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SUSCEPTIBILITY OF THE M52A3B1 PRIMER TO IGNITION FROM STATIC ELECTRICITY GENERATED BY A HUMAN SUBJECT

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Philadelphia, Pennsylvania

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Three lots of primers with resistances of 30,000, 300,000 and approximately 3,000,000 ohms were evaluated for sensitivity from circuits that were synthesized from measurements on small, medium and large human subjects dressed in cold-weather and Arctic army uniforms. Subjects were charged to a known voltage and then discharged into simulators for each of the three primer lots.

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Subject capacitance averaged 50 picofarads for the uniform used at +40°F and 13 picofarads for the 0° and -40°F uniform. Voltages of over 6000 volts were easily produced by subject motion in uniforms.

Threshold tests were made by exposing primers to the human equivalent circuit charged to voltages around the threshold voltage predicted from the Bruceton Sensitivity tests. Threshold voltages were determined by exposing primers to a voltage until one "fire" occurred. At that event the voltage was reduced by 200 volts and exposures began once more. Fifty exposures without a fire constituted establishment of threshold for that primer lot, temperature and equivalent circuit. Lowest threshold voltage was 700 volts. This same level was evaluated at 40°F for lots ES1 and ES3 where subject capacitance was largest (50 picofarads).

Results of exposure of a primer-like gap from human discharge indicated a limit somewhere between 4000 and 6000 volts. Initial voltage of 4000 volts allowed passage of energy into the primer simulator. At 6000 volts, very little energy was perceptible on the load side of the primer simulator gap.

From these data there appears to be an overlap in the stimulus that can be delivered from humans in Arctic uniform and the response of M52A3B1 electric primers. Enough energy can be built up and delivered to reach and exceed the threshold level for the primers.

Efforts were made to minimize losses in the system during primer sensitivity evaluation and these results may well reflect a "worst case" conditions.

Recommendations include;

(1) Completing Energy transfer tests on primer electrodes.

(2) Running future test with equipment and personnel in environmental chamber large enough to house all equipment.

(3) Making transfer measurements with the primers themselves in the circuit.

F-C3967

Report

SUSCEPTIBILITY OF THE M52A3B1 PRIMER TO IGNITION FROM STATIC ELECTRICITY GENERATED BY A HUMAN SUBJECT

by

Charles T. Davey

Prepared for

U. S. Army
Frankford Arsenal

Contract DAAA 25-75-C0175

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THE BENJAMIN FRANKLIN PARKWAY • PHILADELPHIA, PENNSYLVANIA 19103

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ERRATA

1) Page iii, paragraph 2, line 2
+40°F and 13 picofarads . . .

2) Page 1-1, paragraph 1, line 7
. . . good insulators or machinery . . .

3) Page 4-1, paragraph 1, line 6
. . . First trials at firing resulted

4) Page 4-1, last paragraph, line 1
. . . in Bruceton Fashion, [5] i.e., using

5) Page 4-4, paragraph 4, line 3
by 200 volts. . . .

6) Page 4-4

Table 4-2 Threshold* Voltages For Primers

	Threshold Voltage (Volts)		
Lot/Temp. °F.	40	0	-40
ES 1	700	3400	3200
ES 2	1500	2600	2400
ES 3	700	2400	2200

* Highest voltage for which 50 exposures resulted in no fires.

7) Page 5-3
Figure 5-2. Waveforms on Normally Insulated Primer Simulator

8) Page 6-2, paragraph 2, line 3
done inside a chamber of about 20 cubic feet. . . .

9) Page 6-4, Conclusion No. 5
• Bruceton or step type testing . . .

FOREWORD

This work was started with the intent of completing all required work detailed in the program description. It was not possible, within the funds available, to complete this program to the extent desired. Limitations were experienced in physical parameters, particularly in the very low capacitance of human subjects in Arctic uniform (13 picofarads) and the attending problems of leakage resistance, ambient humidity and circuit geometry. All of these become important under the extremely small subject capacitance. The work completed is still, we feel, important to all aspects of humans working in an Arctic environment where electrostatic energy is a factor. Detailed measurement of energy delivery under these conditions are probable unique at the present state-of-the-art.

Final Report F-C3967
"Susceptibility of the M 52A3B1 Primer
to Ignition from Static Electricity Generated
by a Human Subject" by Charles T. Davey
Physical and Life Sciences Department
Applied Physics Laboratory - P. F. Mohrbach, Manager
Frankford Arsenal Contract DAAA 25-75-C0175

W. B. Ligett
Vice President and
Director

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ACKNOWLEDGEMENTS

Allen Schlack, the project officer on this program was most helpful in arranging deliveries, selecting the right components, overcoming barriers and bridging gaps. We appreciate and acknowledge his help on this program.

Ramie Thompson, Senior Staff Engineer, helped with the pulse work in providing proof that the simulator circuits were yielding oscillograms that could be trusted. He developed the technique that was used in obtaining oscillograms.

Joseph Heffron, Technical Associate, carried out most of the experimental work on this project and led the work on an experimental basis.

Tom Tucker and Peter Lydzinski served as subjects and provided other help in completing the reported work.

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TABLES (Cont'd.)

1. INTRODUCTION

1.1 GENERAL

Electrostatic energy has been both a curiosity and a curse. A curiosity at first since the word *electron* comes from the Greek for amber. Even in ancient times static electricity was known.[1]* The ancients did not have the explosive receptors for static electricity that we have today - gasoline, dusts, hign and low explosives including propellants and primers. Neither did the ancients have synthetic fabrics and good insulators or michinery to produce static in larger quantities.

In modern society all of these are available, and as a result, static electricity has become a curse in some instances - when conditions brought together good generators and receptive materials.

Personnel at Frankford Arsenal have been justly concerned with possible interactions of electric cannon primers with personnel dressed in arctic uniform.[2] The uniforms are mainly of synthetic material, the arctic climate is dry and the primer is apparently questionably sensitive to static electricity.

Electric primers offer some advantages over percussion or stab primers including the ability to synchronize events with an electrical impulse. Eliminating the electric primer is therefore not a feasible solution to the potential problem.

With these considerations in mind, the experimental program described in this report was begun.

*Please refer to bibliography at the end of this report for numbered references.

1.2 PROGRAM DESCRIPTION

1.2.1 General

Program requirements are detailed in Appendix A.

1.2.2 Study 1 - Stored Charge and Charge Delivery

The object of this study was to determine the amount of charge on a human subject which could effectively be delivered to a primer simulator.

1.2.3 Study 2 - Determination of the Amount of Energy on a Capacitor Which can be Effectively Delivered to a Primer Simulator

The object of this study was to determine the electrical circuit representative of a human being, and to determine the electrical energy that could be delivered to a primer simulator from that circuit.

1.2.4 Determination of Average Firing Voltage and Threshold Firing Voltage for a Cased Primer

Using equivalent human circuits, determine the mean, distribution and threshold voltages to fire the primer.

1.2.5 Energy Delivered to a Primer Under Simulated Field Conditions

Determine if a human can deliver energy to a primer under simulated field conditions and how much.

1.3 INSTRUMENTATION

Three simulators were to be developed having input resistances of 30,000, 300,000 and 1,000,000 ohms. This simulator was to be used to measure the charge transferred.

Three temperature conditions +40° (30% RH), 0° and -40° and three subjects were to be used.

2. DETERMINATION OF STORED CHARGE ON A HUMAN SUBJECT THAT CAN EFFECTIVELY BE DELIVERED TO A PRIMER SIMULATOR

2.1 PRIMER SIMULATOR DEVELOPMENT

2.1.1 Vacuum Thermocouples (VT)

Vacuum thermocouples are made of a wire heater element to which a thermocouple is attached and the two elements are enclosed in an evacuated envelope (Figure 2-1). These were used at the base of a much larger resistance (R_1) connected in series with the heater element. Experiments proved that the elements could not be used at lower charges (less than 1500 volts) on capacitors of 500 picofarad.

The advantages afforded by these devices is that a single meter reading from an electronic microvolt ammeter gives a measure of the energy delivered to the thermocouple.[3]

2.1.2 Thermistors

Thermistors operate in a manner similar to that of the vacuum thermocouple. Heat input from an electrical pulse is integrated, bringing about a change in resistance.

The advantage of the thermistor over the VT rests in the much larger resistances available. Thinking was that a much larger share of the supplied energy would be converted into measurable heat. Difficulties arose in allowing resistance measuring instruments to remain on the thermocouple during high-voltage pulse application and also in the overload of the initial pulse. Many thermistors were burned out in the process of testing, mainly because of the small size resulting from sensitivity needs. After considerable effort in attempting to make either thermal system operate with limited success, we abandoned each of these in favor of direct photography of oscilloscope traces.

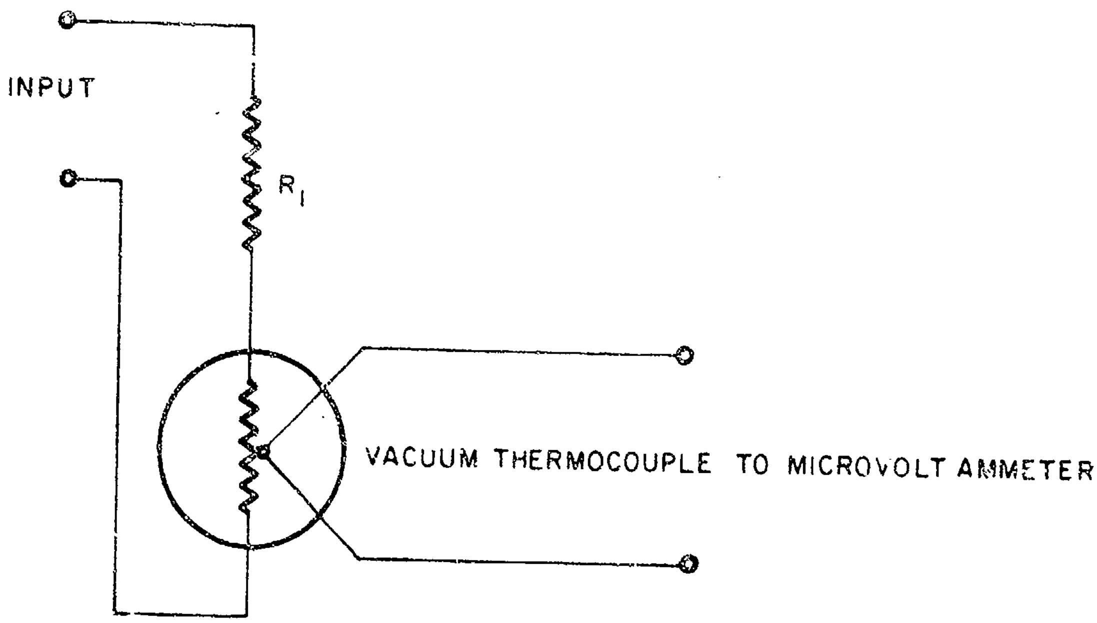

Figure 2-1. Vacuum Thermocouple "ERG Meter"

2.1.3 Oscillography

With short pulses and fast rise times used in this work and with the distributed circuits involved, much effort was expended in developing a simulator circuit that would allow viewing of the pulse with some fidelity.

The circuits ultimately used are of the type illustrated in Figure 2-2 which shows the form of the simulator along with the method of connection to the oscilloscope.

2.1.4 Description of Simulators

The oscillography and the simulators are so closely related that it is difficult to separate them. They are one measuring system. The appearance of the simulator is that shown in the photograph of Figure 2-3. The simulator was constructed so that a return to case was made through the oscilloscope lead which was terminated in a 50-ohm termination at the oscilloscope input. Three simulators were similarly constructed with appropriate resistors in series to give a total resistance of 30K, 300K and 1 Mohm.

The simulators were subjected to a rectangular voltage pulse in order to check response of the system. The pulse was generated by discharging a 50-ohm transmission line.[4] The pulse was formed across a 50-ohm resistor in shunt with the input of the simulator. Output was monitored on the oscilloscope at both top and bottom of the simulator network. Differences in pulses at the top and bottom of the network were indistinguishable in shape. As a result of this test on all three simulators, it was assumed that fidelity was reasonable and that the signal at the oscilloscope truly represented the voltage and current through the simulator network. This assumption, backed by experiment, allows calculation of energy based on a single waveform taken at the oscilloscope. There is no need to measure both voltage and current.

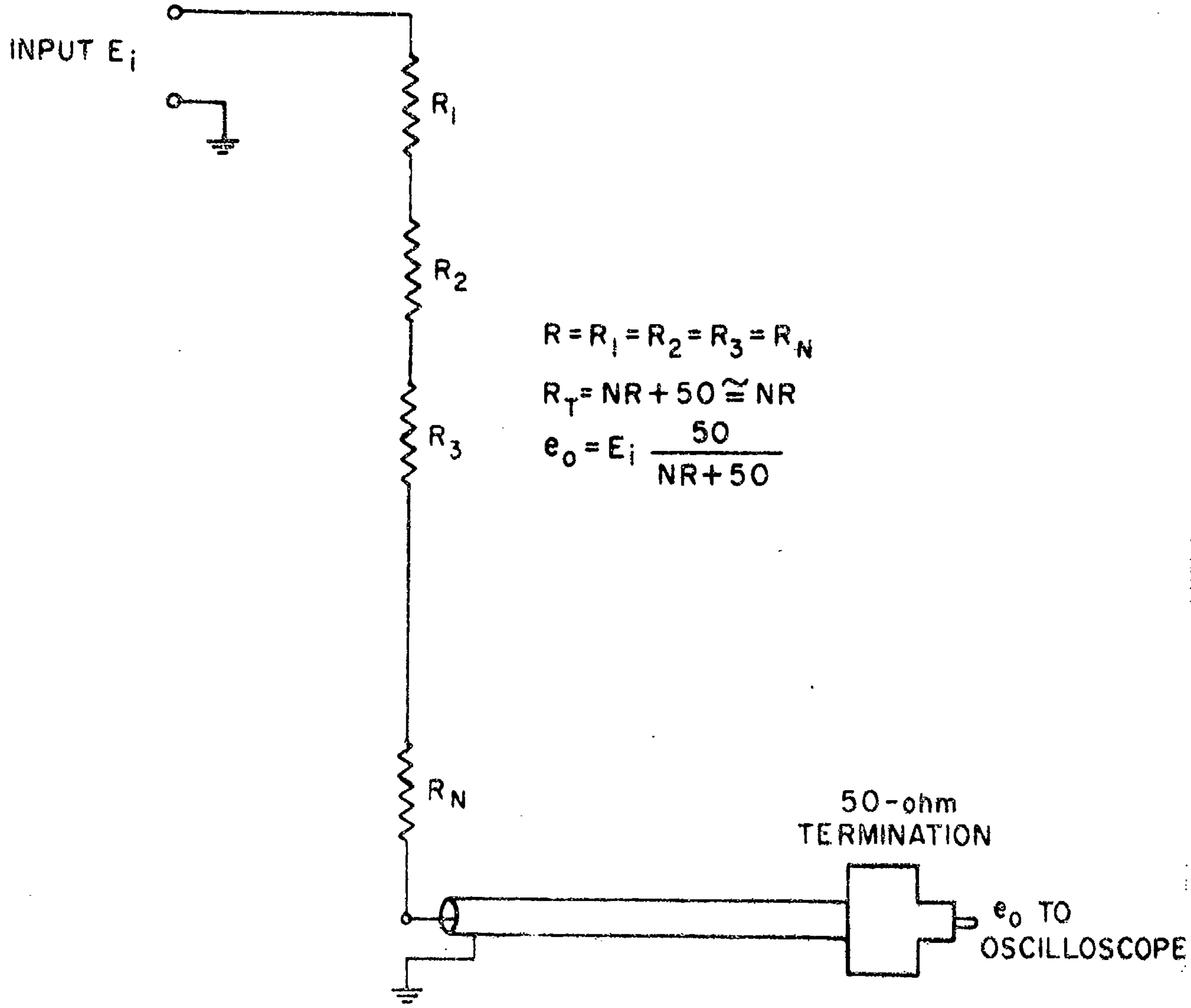

Figure 2-2. Circuit of Simulator

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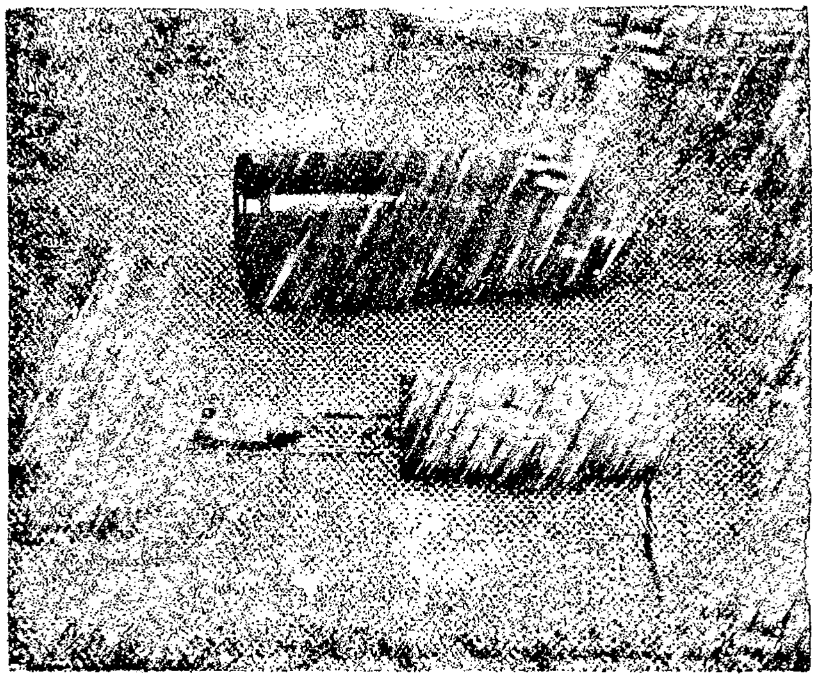

Figure 2-3. Construction of Simulator

2.2 TESTING PROCEDURES

2.2.1 Uniforms

Uniform choice was made in cooperation with the Project Officer. Table 2-1 lists the clothing used. Two sets were required, one for +40° and another for 0° and -40°. Figure 2-4 shows medium and large subjects, in the heavier clothing. The shed clothing is stacked in front of the subjects. Figure 2-5 shows the small subject in lighter clothing.

2.2.2 Testing at 40°F, 30% RH

Human testing was begun at FIRL in a conditioned room. Operation at 40°F was at the lower limit of the room.

Problems with equipment were worked out here to avoid the complications which would arise from the same problems in outside facilities while making tests at 0°F and -40°F.

2.2.3 Testing at 0° and -40°F

Subjects required working room. Original plans were to do this testing at Temple University, however the facilities did not provide for tests at 0°F and -40°F. For this reason tests were carried out at Frankford Arsenal.

All other testing was carried out in a Murphy and Miller environmental chamber at The Franklin Institute.

2.2.4 Results of Human Testings

Three human subjects were used throughout all testing. Oscillograms exemplified in Figure 2-6 were made of each test condition. At least five to ten shots were made of each test condition on a single piece of polaroid film. The traces were then averaged and the average trace analyzed on a step by step basis by computing the energy in parcels of time. These energy parcels were added to give the total energy delivered to the simulator. Results are tabulated in Table 2-2. There is no

Table 2-1. Uniform Descriptions

UNIFORM 1 FOR 40°F

Clothing Descriptions	Army Designation Number
Undershirt Men's: Cotton OG 109	8420-782-6709 6710 6711
Underdrawers Men's Cotton OG	8420-782-6406 6407 6408
Drawers, cold weather, 50 cotton, 50 woll	8415-904-5120 5121 5122
Undershirt Men's, 50 cotton, 50 wool	8415-904-5136 5137 5135
Shirt Flyers; Men's HTRN	8415-935-4895 4898 4901
Trousers Flyers; Men's HTRN	8415-935-4882 4885 4888
Socks Men's, 25 cotton, 75 wool	8440-153-6718 6719
Boots combat, leather, OMS 10-1/2H	8430-782-3104 3109
Jacket Flyers, inter. wt. MA-1	8415-818-7352 7353 9133
Cap, cold weather, 107	8415-782-2918 2919 2920
Gloves, Flyers, GS/FRP-1	8415-935-6329 6331

Table 2-1. Uniform Descriptions (Cont'd.)

UNIFORM 2 FOR 0°F & -40°F

Clothing Descriptions	Army Designation Number
Undershirt Men's: Cotton OG 109	8420-782-6709
	6710
	6711
Underdrawers Man's Cotton OG	8420-782-6406
	6407
	6408
Undershirt Men's, 50 cotton, 50 wool	8415-904-5136
	5137
	5138
Drawers, cold weather, 50 cotton, 50 wool	8415-904-5120
	5121
	5122
Shirt Flyers; Men's HTRN	8415-935-4895
	4898
	4901
Trousers Flyers; Men's HTRN	8415-935-4882
	4885
	4888
Socks, Men's, 25 cotton, 75 wool	8440-153-6718
	6719
Trousers, Ext., cold weather Ctn Ny I	8415-782-2950
	2954
	8415-265-0367
Liner, cold weather trousers 6.2.2 Ny I	8415-261-6859
	6854
	6857
Coat, cold weather Ctn Ny I	8415-782-2935
	2939
	2943
Liner,cold weather coat 6.202 Ny I	8415-782-2887
	2888
	2889

Table 2-1. Uniform Descriptions (Cont.d.)

Trousers, Flyers, Nylon, Heavywt.	8415-269-0521 0523 8415-266-9890
Parka, Ext. cold weather	8415-223-7624 8415-782-3218 3219
Liner, Ext. cold weather, Nylon	8415-240-2462 2460 2461
Hood, Ext. cold weather w/fur cuff	8415-266-7750
Cap, cold weather ctn-nylon	8415-782-2918 2919 2920
Mitten set arctic, gauntlet	8415-268-7690 7693
Mitten insert wool & nylon OG	8415-160-0769 1376
Boots extreme cold weather	8430-655-5549 5535 5563
Mask extreme cold weather	8415-243-9855

Figure 2-4. Large and Medium Subjects in Uniform 2 for Sub-Zero Temperatures

Figure 2-5. Small Subject in Uniform 1 (40°F)

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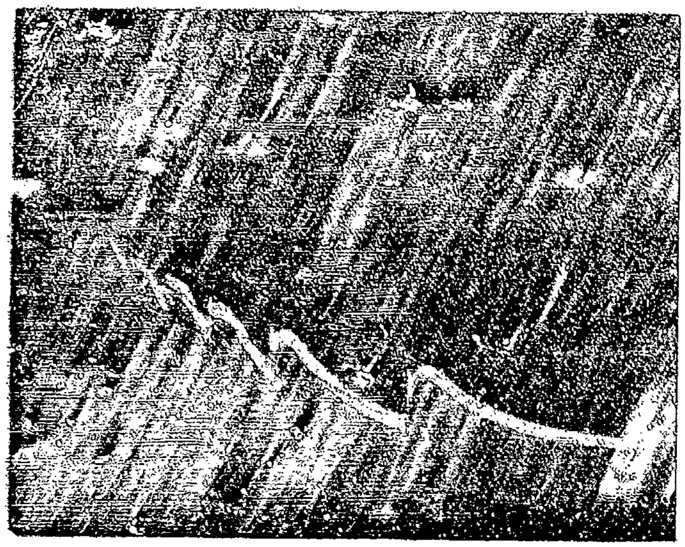


5 microseconds/cm
20 millivolts/cm (at oscilloscope)
1600 Volts Peak at Simulator Input
1 Megohm Simulator

Figure 2-6. Typical Discharge Trace from Human Subject Initially Charged to 3,000 Volts.

Table 2-2. Energy Delivered to Simulators by Human Subjects
(Ergs)

Subject/Environment Uniform	Test Voltage (Volts) 500	1500	3000	4500	6000	Simulator Resistance (k ohms)
Small/40°F Uniform 1	16	266	1540	3420	9660	30
	54	275	1360	3180	6480	300
	9	353	1050	2570	5340	1000
Medium/40°F Uniform 1	18	427	1730	3800	6820	30
	46	294	2070	3560	9040	300
	51	480	1240	3290	6040	1000
Large/40°F Uniform 1	33	539	2330	5120	12100	30
	24	450	1730	4140	7210	300
	20	550	1190	2660	5860	1000
Small/0°F Uniform 2	3	56	251	841	1480	30
	2	30	160	615	1060	300
	3	47	252	673	1200	1000
Medium/0°F Uniform 2	3	70	269	660	1140	30
	7	29	154	442	914	300
	3	3	131	490	920	1000
Large/0°F Uniform 2	8	38	177	356	847	30
	1	24	142	360	967	300
	1	38	168	498	779	1000
Small/-40°F Uniform 2	2	80	261	681	1950	30
	2	52	257	602	1210	300
	4	39	180	831	1390	1000

Table 2-2. Energy Delivered to Simulators by Human Subjects (Cont'd.)
(Ergs)

Subject/Environment Uniform	Test Voltage (k volts)					Simulator Resistance (k ohms)
	500	1500	3000	4500	6000	
Medium/-40°F						
Uniform 2	3	83	344	681	1010	30
	2	24	281	608	1390	300
	3	15	202	535	1230	1000
Large/-40°F						
Uniform 2	2	82	263	632	880	30
	2	38	172	512	984	300
	1	23	183	433	813	1000

question that substantion amounts of energy are being delivered to the simulators under these circumstances.

2.2.5 Methods of Delivering Energy

One primary problem area was in providing a charge to the operator and in delivering the energy thus stored to the primer. The subject was to wear gloves according to the uniform specified.

An interesting and essential part of working with charged humans arose while early tests were being made. Examination of the environmental room revealed that no high-voltage power supply was present. Just prior to this examination oscillograms were being taken with the instruments outside the chamber. Inquiring how the subject was charged, the method was revealed. He simply jumped on and off of the insulated platform a few times while reading the potential on an electrostatic voltmeter. This process produced body potentials higher than 6000 volts, the level necessary for testing. The possibility of charge building is thus demonstrated clearly.

The jumping process was slow and was soon replaced with a high voltage power supply. A vacuum relay was first used to connect the subject to the simulators. The switch bounced a great deal and gave waveforms that were not suitable for analysis. As a result, a hand held tool or wand was used with more reasonable waveforms. The subject touched an electrode with the wand (or probe) held in his hand to charge himself. The wand was then moved to an electrode connected to an electrostatic meter. After recording the correct voltage the wand was transferred through the air to the electrode of the primer simulator in approximately three seconds.

The wand was simply a 3-inch long handle, one inch in diameter to which was attached a 3/16-inch diameter shaft about 3 3/4 inches long. The tool was much like a screw driver. It was constructed of stainless steel.

3. EQUIVALENT CIRCUIT FOR HUMANS

3.1 MATCHING CRITERIA

3.1.1 Capacitance

Capacitance was of importance in realizing an equivalent circuit. For this reason a series of measurements were made during tests at various conditions of temperature for each of the three subjects. Results are shown in Table 3-1. Generally the capacitance values reflect the uniform that was used. Gloves and footware appear to have the most vivid effects.

All measurements were made with the wand (or tool) in the subject's hand. The wand was connected to a Tektronix LC meter which was used to determine capacitance.

3.1.2 Resistance

Several ways of determining resistance were tried as evidenced by the data in Table 3-2. Energy transfer, peak voltage and RC time were all tried in an effort to arrive at proper series resistance equivalent, the aim being to achieve the equivalent circuits of the human operators.

Series resistance, in every way it was computed, changed with load resistance; the higher the load resistance, the higher the series resistance. Figure 3-1 shows the results of these calculations. Appendix B discusses the method of calculation and shows detailed results.

3.1.3 Experimental Results

A circuit was set up to compare human equivalent circuits with those obtained experimentally. The objective was to begin with the measured capacitance, and then to add necessary series resistance to duplicate the human circuit. A 50 picofarad capacitance was used for the human equivalent of uniform 1 and a 20 picofarad capacitor for uniform 2.

Table 3-1. Capacitance Measurements on Human Subjects

Temperature - °F	Subject	Capacitance (picofarads) Reading 1	2	3	Average
40	Small	45	43	43	44
	Medium	56	56	--	56
	Large	50	43	45	46
0	Small	22	14	--	18
	Medium	--	15	--	15
	Large	11	15	--	13
-40	Small	14			14
	Medium	15			15
	Large	16			16

Notes: Measurements made with Tektronix LC Meter.
All measurements were made with subject in gloves.
Gloves were larger and thicker at 0 and -40 than at 40.
Test tool was in subjects hand during measurements.

Table 3-2. Compiled Data for Resistance Equivalency

Subject	Temp. °F	Photo. No.	Simulator K	Cap. Ave. [illegible]	Energy Trans. Ergs.	$1/2\ CV^2$ 3KV Ergs	$V_p(50)$ mv	V_p v	TC sec	RC sec
Small	+40	3	30	44	1540	1350	4100	2460	1.5	1.3
Medium	+40	18	30	56	1730	2420	4100	2460	1.7	1.7
Large	+40	33	30	46	2530	2070	4200	2520	2.1	1.4
Small	+40	8	300	44	136		370	2220	13.0	13.2
Medium	+40	23	300	56	2070		410	2460	18.5	16.8
Large	+40	38	300	46	1730		380	2280	17.5	13.[illegible]
Small	+40	13	1000	44	1050		108	2160	44	44
Medium	+40	28	1000	56	1240		106	2120	52	56
Large	+40	43	1000	46	1190		100	2000	46	46
Small	0	48	30	14	251	630	2400	1440	0.58	0.42
Medium	0	53	30	15	269	675	2500	1500	0.64	0.45
Large	0	58	30	15	177	675	2100	1260	0.54	0.45
Small	0	63	300	14	160		200	1200	5.4	4.2
Medium	0	68	300	15	154		183	1100	6.4	4.5
Large	0	73	300	15	142		200	1200	4.4	4.5
Small	0	78	1000	14	252		80	1600	17.5	14
Medium	0	83	1000	15	131		67	1340	11.0	15
Large	0	88	1000	15	168		68	1360	14.5	15
Small	-40	93	30	14	261	630	2600	1560	0.58	0.42
Medium	-40	98	30	15	344	675	2700	1620	0.64	0.45
Large	-40	103	30	16	263	720	2400	1440	0.56	0.48
Small	-40	108	300	14	257		240	1440	6.0	4.2
Medium	-40	113	300	15	281		250	1500	6.2	4.5
Large	-40	118	300	16	172		210	1260	4.8	4.8
Small	-40	128	1000	14	180		60	1200	23.5	14
Medium	-40	123	1000	15	232		76	1520	14.0	15
Large	-40	133	1000	16	183		72	1440	13.5	16

Notes: $V_p(50)$ = Peak voltage across 50 ohm load.
V_p = Peak voltage at simulator input.

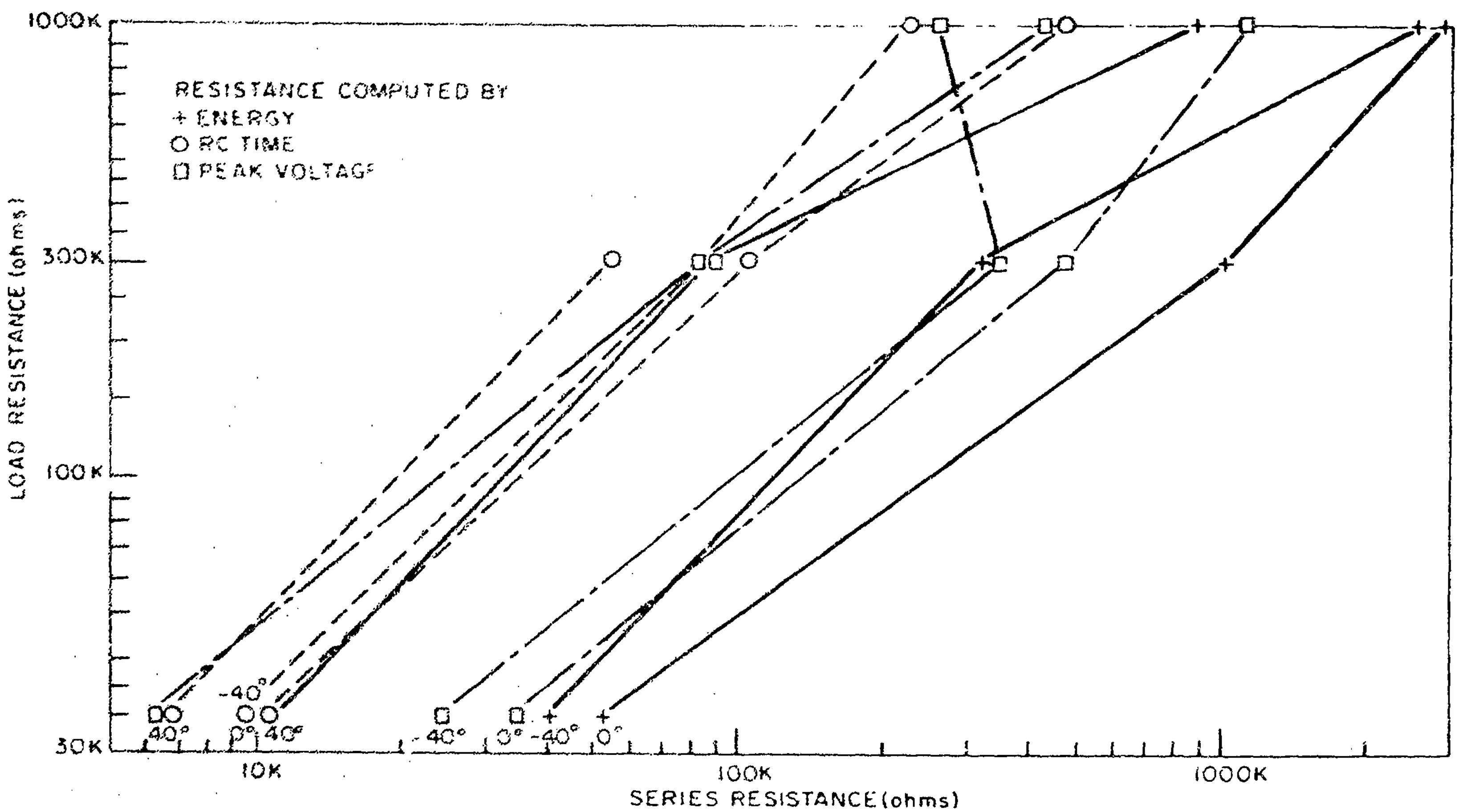


Figure 3-1. Variations in Series Resistance With Load Resistance

Several tests showed that the series resistance observed in human testing was the result of switching; and since the human testing and the equivalent circuit involved a switching action this resistance was already present in the circuit. A reasonable match was obtained directly, without the need for additional series resistance. Conditions of the match are indicated in Table 3-3. As a result of these findings, only the capacitors were used as equivalents. Further checks were made on all three simulators in the environmental chamber.

Table 3-3. Matching Data

Human Energy Transfer vs. Capacitor Energy Transfer

Simulator	Energy Transfer (Ergs) Human Subject	Capacitor
30K	2050	1870
300K	1720	1750
1M	1450	1160
30K	261	390
300K	194	290
1M	186	233

Note: Both subject and capacitor capacitance was the same at 40°, .50 pf. At 0 and -40°F, subject was 13 Pf and capacity 20pF. Matching was done under ambient, room conditions.

4. DETERMINATION OF AVERAGE FIRING VOLIAGE AND THRESHOLD VOLTAGE

4.1 DETAILED TEST METHODS

All primer lots were randomly sampled using a table of random numbers. Testing was performed in a small test chamber. A firing fixture was used to hold the 20mm cartridge cases. Connection to the primer was made via a small coaxial connector that was designed and built specifically for this purpose. The problem was to provide adequate insulation and strength to test a number of primers. First trails at firing resulted in interface problems at the connection point. It was apparent that arcing and losses were occurring at voltages as low as 3000 volts.

The origin of the problem was either the connector or the cased primer itself. To avert the problem, a spot of silicon grease was placed on each primer covering the button and insulation prior to conditioning the primer lot. The logic in doing this was to determine a worst-case condition for the primer. Not to apply the grease was to invite very erratic performance and to gather little or no performance data. Even with these precautions some lots behaved badly with Bruceton type testing.

Threshold tests were made with the primed cases treated in the same manner. Figure 4-1 shows the firing switch that was used. The handle was actuated to the charge position and then released to allow the "capacitor" sphere to drop unto the "primer" sphere.

4.2 BRUCETON TESTS

Each of nine tests was fired in Bruceton ashion, [5] i.e., using step tests with data concentrated about the mean. Results of these tests are summarized in Table 4-1. Each individual Bruceton test is presented in Appendix C.

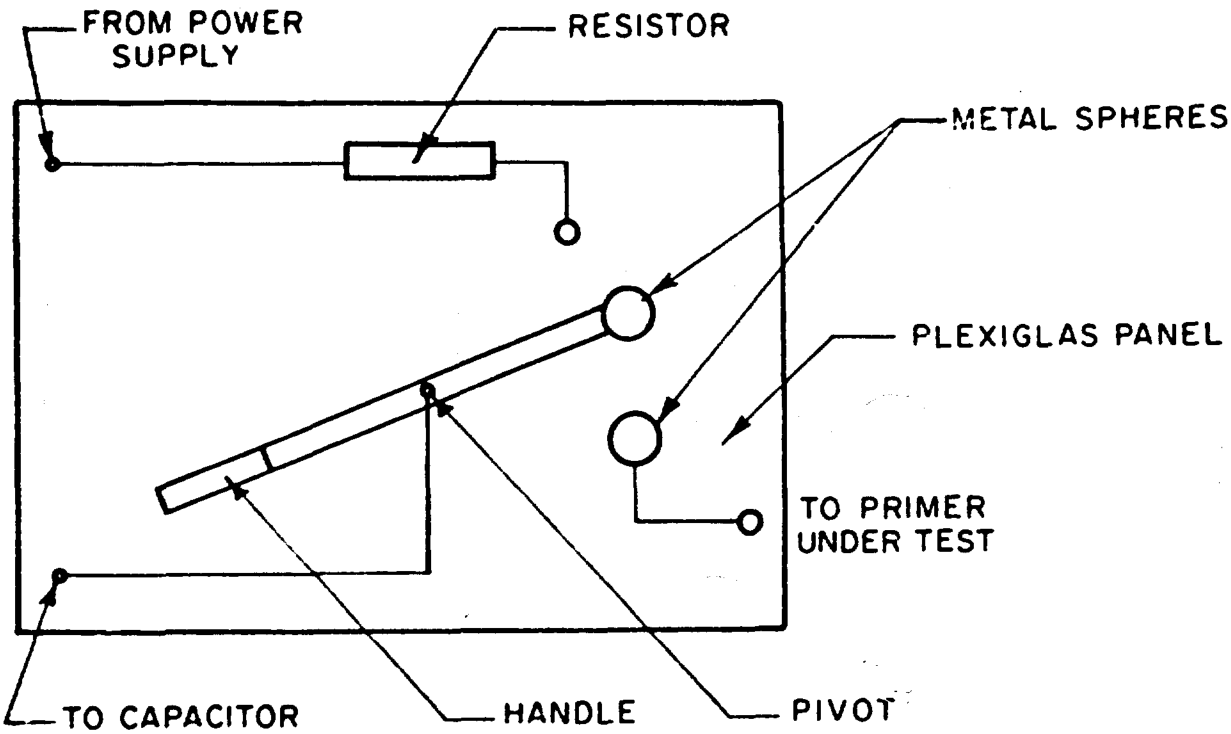


Figure 4-1. Spherical Electrode Firing Switch

Table 4-1. Summary of Bruceton Tests From Simulated Human Circuits

Condition Temp-°F	Lot	Mean		Std Dev.	Dispersion Data - Predicted Firing Voltage (Volts)						
		Log Volts	Volts	Log Volts	p_2 0.1%	1%	10%	90%	99%	99.9%	Confidence %
40°, 30%	ES1	3.57048	3719	.06403	1864	2205	2778	4980	6273	7421	90
					1738	2090	2693	5136	6617	7962	95
	ES2	3.58898	3972	.20572	362	680	1452	10,160	24,270	43,600	80
					274	530	1290	12,240	29,330	57,600	95
	ES3	3.83402	6824	.07134	3325	3960	5024	9270	11,760	14,000	90
					3122	3770	4880	9540	12,340	14,900	95
0°	ES1	3.93414	8593	.07481	4030	4843	6226	11,860	15,250	18,322	80
					3768	4600	6040	12,200	16,050	19,600	95
	ES2*	4.0120	10,280	.2321	1960	2960	5130	20,600	35,700	54,000	None
	ES3	3.85308	7130	.33108	103	291	1210	42,000	175,000	494,000	90
					59	190	956	53,200	264,600	862,300	95
-40°	ES1	3.86202	7278	.14334	1511	2216	2749	14,130	23,903	35,065	90
					1281	1955	3488	15,184	27,100	41,354	95
	ES2*	4.2776	18,950	.5111	500	1230	4200	85,400	292,400	719,300	None
	ES3	4.20613	16,074	.43376	37	165	1275	203,000	1,568,000	6,926,000	90
					16	87	892	290,000	2,975,000	1.6×10^7	95

*Mean and STD Dev. determined by probit.
Dispersion data given without confidence.
Voltage source was capacitor in each instance, 50 picofarads for +40°F and 20 picofarads for 0° and -40°F.

Actual execution of the tests was difficult. The main problem was with "off-set" during the progress of the Bruceton.

In several instances the number of firing levels exceeded those permissible for analysis. In two cases a Probit Analysis[6] was used to compute the means (Lot ES2 at 0° and -40°) when excessive levels were encountered.

The wide variations in log standard deviation (Table 4-1) demonstrate wide lot-to-lot variations. Generally the standard deviations were larger under colder conditions. Predicted voltages for 0.1, 1, 10, 90, 99 and 99.9% functioning probabilities based on a normal model are listed in the table for 90 and 95% confidence intervals. Interpretation of these data must be done cautiously since this working capacitance is extremely small and factors contributing to firing, including losses, are not well understood or controlled. These dispersion data were used to estimate the levels for the threshold voltage test that follow.

4.3 THRESHOLD TESTS

Threshold testing was accomplished by exposure of a number of items at one level until a "fire" occurred at which time the level was decreased by 200 bolts. When 50 "no-fires" were found at one level testing was terminated. Table 4-2 shows threshold levels established. Complete test results are given in Table 4-3.

Table 4-2. Threshold* Voltages for Primers

	Temp. °F	Threshold Voltage (Volts)	
Lot	40	0	-40
ES 1	700	3400	3200
ES 2	1500	2600	2400
ES 3	700	2400	2200

*Highest voltage for which 50 exposures resulted in no fires.

Table 4-3. Threshold Test Results

Temp-F Lot	-40			0			40		
ES1	Voltage Volts	Fires	Exposures	Voltage Volts	Fires	Exposures	Voltage Volts	Fires	Exposures
							700	0	50
	3200	0	50				900	1	32
	3400	1	47	3400	0	50	1100	1	10
	3600	1	7	3600	1	8	1300	1	16
	3800	1	6				1500	1	28
							1700	1	17
							1900	1	47
							2100	1	10
							2500	3	3
ES2									
	2400	0	50	2600	0	50	1500	0	50
	2600	1	29	2800	1	27	1700	1	15
	2800	1	16	3000	1	5	1900	1	10
	3000	1	46						
	3200	1	34						
	3400	1	19						
	3600	1	25						
	3800	1	31						
	4000	1	32						
	4200	1	3						
	4400	1	17						
	4600	1	4						
	4800	1	26						
	5000	1	6						
ES3	2200	0	50	400	0	50	700	0	50
	2400	1	20	2600	1	47	900	1	27
	2600	1	24	2800	1	5	1100	1	34
	2800	1	8	3000	1	5	1300	1	15
	3000	1	32				1500	1	5
	3600	1	20				1700	1	5
	4000	1	9				1900	1	10
							2100	1	5
							2300	1	5
							2500	1	5
							2700	3	12
							2900	2	5
							3400	3	4

These tests were hampered by conditions outside the chamber. Hand holes were needed to reload each of the 20mm cases and to activate the switches. These openings resulted in some creation of "snow" inside the chamber when ambient conditions were moist.

4.4 SUMMARY

The threshold voltages in Table 4-2 are the result of experiments at or near the threshold. Comparison of these threshold values with predictions derived from the Bruceton reveals that either or both of these data sets are highly questionable.

Physical reasoning shows numerous critical conditions all of which result from the use of small firing capacitors (50 and 20 picofarads):

(1) Any small changes in shunt capacitance on the load side of the switch.

(2) Leakage resistance from the switch pole to ground.

(3) Leakage resistance shunting the primer.

While in each experiment efforts were made to keep conditions as specified, apparently some conditions are not under control.

5. RESULTS OF ARC GAP TESTS

5.1 SIMULATOR FITTED WITH ARC GAP

The primer simulators were constructed with a central electrode which protruded approximately 1/2 inch beyond the end of the cartridge case (see Figure 5-1). This electrode was well insulated from the case by a rather substantial teflon sleeve. While this configuration facilitated testing, it differed significantly from the actual primer, in which the central electrode is insultated by a 0.020 thick polyvinyl chloride washer.

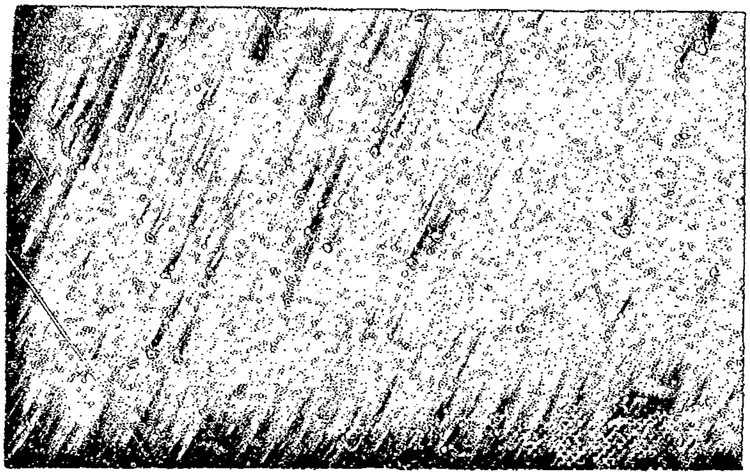
To better duplicate this condition the simulator was fitted with a metal cap which contacted the cartridge case and was insulated from the central electrode by a 0.015-inch thick sleeve of teflon. This cap was placed on the one megohm simulator and tested at 0°F using the small size subject.

At 6000 volts the scope was triggered but there was no deflection of the trace as is evident in Figure 5-2. An arc was observed across the teflon insulator.

At 4000 and 2800 volts discharge traces were recorded as can be observed in Figure 5-2 middle and bottom traces.

Energy computations were made on the 4000-volt and 2800-volt waveforms of Figure 5-2. With an initial charge of 4000 volts, the energy delivered to the simulator through the arc-cup was 348 ergs. This energy represents approximately 33% of the energy initially stored on the subject computed by $1/2\ CV^2$ ($1/2 \times 13 \times 10^{-12} \times \overline{4000}^2 = 1040$ ergs).

At 2800 volts, similar computations give an energy of about 190 ergs and an efficiency of 37%. Efficiency at the lower voltage (37%) was higher than the efficiency for the higher voltage (33%). These comparisons may be significant because this trend goes counter to the



Components of Primer Simulator

Assembled Primer Simulator with
Electrode on Top

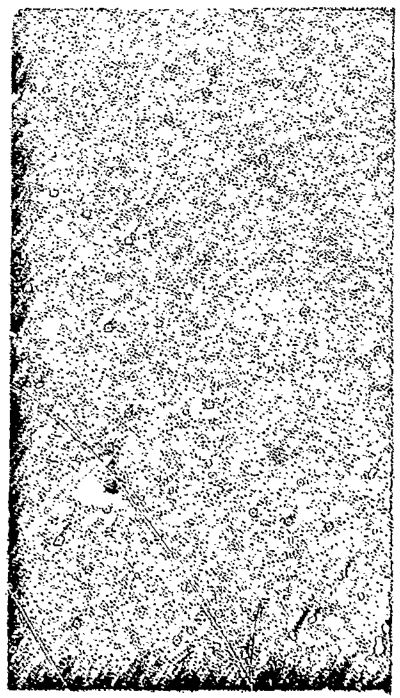
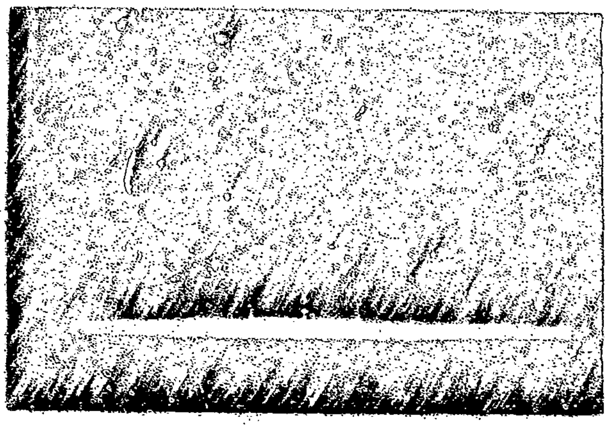
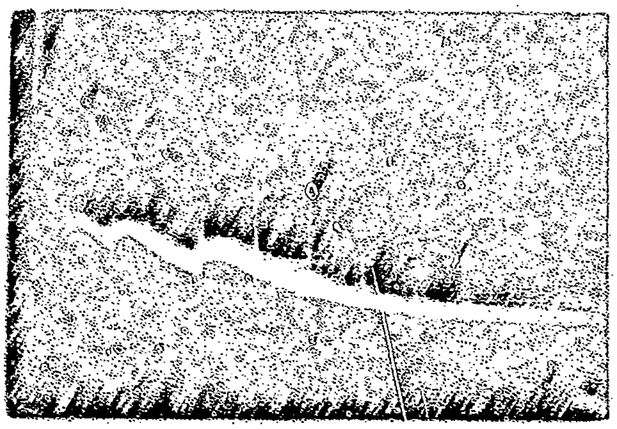


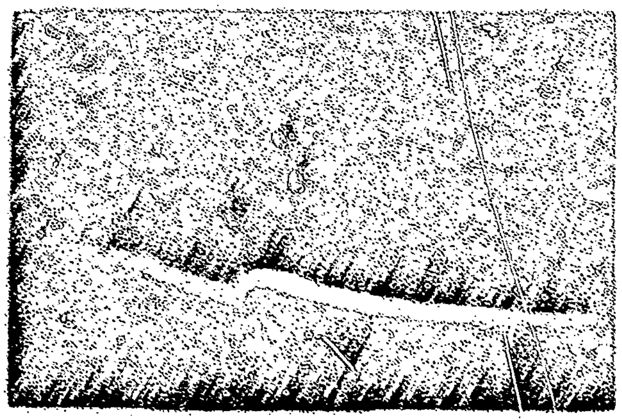
Figure 5-1. Electrode Configuration of Primer Simulator



6000 Volt Charge-Small Subject
1 Megohm Simulator
50 mv/cm Vertical
5 Micro sec/cm/tor 3



4000-Volt Charge



2800-Volt Charge

Figure 5-2. Waveforms on Normady Insulated Primer Simulator

one where the arc-cup is not used, as may be seen in Table 6-2 where efficiencies always increase with increasing initial voltage.

A further comparision was made in this manner. The data from Table 2-2 (small/0°F/1000 kilohms) were plotted on log-log paper and a straight line was obtained whose equation is log E = -6.164 +2.459 log V. The energies transferred at 4000 and 2800 volts were determined to be 493 and 205 ergs. It is seen that there is a considerable difference in the amount of energy transferred at the higher voltage when the primer simulator is electrically connected to the source compared to when the suject approaches the primer simulator. At the lower voltage the amount of energy transferred is similar with and without the arc gap.

6. DISCUSSION OF RESULTS, CONCLUSIONS AND RECOMMENDATIONS

6.1 DISCUSSION OF RESULTS

Behavior of the primer and the equipment used to evaluate its sensitivity was not expected to be tightly controlled; it wasn't. It was more manageable than was originally anticipated.

Human capacitance values are normally considered to be around 300 to 500 picofarads with normal clothing.[7] Arctic military uniforms including gloves reduce the value of capacitance to 13 picofarads for the uniforms used under extreme cold conditions (Uniform 2). The intermediate uniform produces a capacitance of about 50 picofarads. Both measurements were made with the subject holding a "tool" in his hand.

A simple series resistance network with a 50-ohm line and termination at the base of the network proved best for simulation. Checks on this network in the sub-microsecond time revealed that the oscilloscope reproduced input waveforms within the range of voltage magnitude used for excitation in tests. This method of determining transfer of voltage, current and energy is acceptable.

Waveforms taken from charged human subjects were analyzed by integration to give the energy delivered to the simulators. Switching of the subject was tried by use of vacuum relays. These were unsatisfactory because of bounces that occurred during the span of the discharge waveform. Better results were achieved using the stem of the hand-held tool to charge the subject from a preset power supply and to discharge the subject with the simulator.

Examination of the resistance properties of the subjects during discharge showed that these values were not constant with varying load. The apparent series resistance increased and decreased directly with load resistance. First thoughts were that simulation of the human

circuit would be difficult; however a few experiments showed that the resistance was not some value lumped in the human, but rather mainly the result of the switching contacts on the tool used in human transfer and the double-ball switch used in firing primers from human simulated circuits.

Firing tests were problematical in some instances. Selection of the interval between excitation levels is important to achieve good results in any step type test. Too wide an interval results in successive fires and misfires. Too narrow an interval results in huge runs of fires or misfires. About five to seven levels is a desirable compromise which at times, were achieved. Many tests had to be restarted after running into a long "shift" in levels.

It was not possible to isolate the exact cause of these runs. Some thoughts are that the outside humidity affected results. Firings were done inside a chamber of about 20 cubit feet. Access to the chamber was needed to change cases and fire them. As a result of this procedure, frost formed on the inside of the chamber.

Despite problems, we believe that these results represent the first step type tests that were made from circuits representing humans. Standard deviations indicate that lot ES1 was best behaved. The lowest value of standard deviates was achieved in lot ES1 at +40°F. Others were normalized using this value as one with results shown in Table 6-1.

Table 6-1. Normalized Standard Deviations

Lot/Temp. °F	40	0	-40	Ave by Lot
ES1	1.0	1.17	2.24	1.47
ES2	3.21	3.62	8.67	5.17
ES3	1.11	5.20	7.09	4.47
Ave by Temp	1.77	3.33	6.00	

Lot ES1, ES3, and ES2 are the best to worst behaved in the order listed based on evaluation by standard deviation. It is also clear from these results that behavior becomes less predictable as the temperature is lowered. Part of this we believe to be ambient conditions outside the chamber used for sensitivity testing.

In terms of energy transfer, data listed in Table 6-2 are appropriate.

Table 6-2. Energy Transfer Efficiencies by Temperature and Initial Voltage

Temp./Voltage °F Volts	500	1500	3000	4500	6000
40	.48	.72	.70	.70	.85
0	.21	.25	.32	.41	.44
-40	.14	.33	.43	.47	.52

The values listed are computed by dividing the average measured energy, irrespective of load, at each temperature by the energy (1/2 CV^2) on the average capacitance of the subjects at that temperature. Two effects are noticable from these data. (1) Efficiency increases with initial voltage and (2) efficiency is generally lower at 0° than at either + or -40°F.

Threshold voltages (Table 4-2) lots ES 1 and ES 3 were much lower than the predicted 0.1% point (Table 4-1). These differences are suspected to be caused by conditions external to the chamber. Generally lower humidities outside the environmental chamber favor lower voltages for firing the primer. Records of humidity outside the chamber were not kept in the beginning; and as a result, there is no continuity of data on which to base firm conclusions on the effects of ambient humidity.

The ability of persons uniform to generate charge was demonstrated during these tests. Voltages in excess of 6000 volts were generated on human subjects by physical activity alone. The synthetic clothing is no doubt, one of the major contributing factors in this charge build up.

Sensitivity (response) data and the ability of the human to generate and deliver charges do overlap. There are several factors that most probably prevent firing of these primers during use. Remember, the data presented here are "worst case" in terms of sensitivity. Special precautions had to be taken to prevent arcing in the area of the case contact. Tests without these precautions showed arcing to occur somewhere between 4000 and 6000 volts and perhaps at lower values. Threshold tests indicated that some fires could be expected when excitation was as low as 700 volts.

6.2 CONCLUSIONS

- There is overlap in the driving force from electrically charged humans and the response of the subject primer.
- Human capacitance in cold weather army uniform averages 50 picofarads for the 40°F uniform and 13 picofarads for sub-zero arctic uniform.
- Series resistance in circuits comprised of the human, switch and a load varies with the load resistance.
- Persons in Arctic Uniform can easily generate potentials in excess of 6000 volts.
- Bruceton or step type tsting around the mean does not produce results which are compatible with threshold tests. Reasons are probably very low capacitance and variable electrical leakage in equipment in addition to the primer's variability.
- Electrical transfer efficiency of humans increases with increasing initial voltage (48 to 85% going from 500 volts to 6000 volts at 40°F). Efficiency decreases as temperature is lowered.

6.3 RECOMMENDATIONS

- Any further t sting should be carried out in large environmental chambers or under actual arctic conditions where boundry effects can be kept to a minimum. Influence of the warmer and more humid environment around small chambers appears to affect results.

- The presence of overlap in response and driving function under worst case condition makes further examination of this problem imperitive. At this point the reality of the overlap cannot be fully assessed.

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Appendix

A

TECHNICAL SCOPE OF WORK

SECTION F - SPECIFICATIONS

Date 11 May 1973

TECHNICAL SCOPE OF WORK
FOR
STUDY TO DETERMINE THE SUSCEPTIBILITY OF THE M52A3B1
PRIMER TO IGNITION FROM STATIC ELECTRICITY
GENERATED BY A HUMAN SUBJECT

PREPARED

Project Engineer

APPROVED

Ch, Pyro Dev 'Br.

RELEASED

Ch, Sm Cal Prop & Pyro
Dev Lab

SCOPE OF WORK

This technical scope of work prescribes the method of determining the susceptibility of the M52A3B1 primer to ignition from static electricity generated by a human subject. The following documents of the issue in effect on the date of invitation for submission of proposals form a part of this technical scope of work.

1. Drawings
   a. D7548066 - Dwg.Rev.H dtd 9/28/71-Primer, Electric, M52A3B1, Assembly
   b. D7553815 - Rev. P dtd 5/24/72 - Case, Cartridge, 20mm, M103

2. Specification
   a. MIL-P-1394D 6/26/67 and Amend. 1-2/27/70 - Primer, Electric, M52A3B1

The contractor shall furnish such technical and supporting services, materials, equipment and documents as is essential to the attainment of the requirements detailed in the following paragraphs.

The following four studies are to be conducted:

1. Determination of the amount of stored charge on a human subject which can be effectively delivered to a primer simulator

2. Determination of the amount of stored charge on a capacitor which can be effectively delivered to a primer simulator

3. Determination of $\overline{V}$ and threshold voltage required to ignite a cased M52A3B1 primer

4. Determination of the amount of stored charge on a human subject which can be delivered to a primer simulator under simulated field conditions

All four studies are to be conducted under the following environmental conditions: +40°F.(30% relative humidity), 0°F. (no humidity requirement), and -40°F. (no humidity requirement). For informational purposes the humidity should be measured and recorded at temperatures of 0° and -40°F. For those studies in which a human subject is used, said subject is to be dressed in typical Army uniform for each environmental condition evaluated. Initially the capacitances and resistances of three subjects to be used in these studies will be determined for each environmental condition. The experimental details on each study are given in the following four paragraphs.

Study 1 -- Determination of the amount of stored charge on a human subject which can be effectively delivered to a primer simulator. The subject will be charged to the test voltage while standing on an insulated platform. Next the subject will be disconnected from the voltage supply and connected to a device assembled in a M103 case which simulates the primer, such as a resistor. The energy delivered to the primer simulator will be measured. This test will be conducted on each of three human subjects using primer simulators having resistance values of approximately 30,000 ohms, 300,000 ohms and 1,000,000 ohms. The subjects will be charged to each of the following voltages: 1) 500 volts, 2) 1500 volts, 3) 3000 volts, 4) 4500 volts and 5) 6000 volts. Table 1 lists the tests to be performed on each of the three human subjects.

Study 2 -- Determination of the amount of stored charge on a capacitor which can be effectively delivered to a primer simulator. From the capacitance and resistance data obtained, select R-C circuits which represent the average human subject for each environmental condition evaluated. Connect each appropriate R-C circuit to the voltage supply and charge the capacitor to the test voltage. The circuit will then be disconnected from the voltage supply and connected to the primer simulator fabricated in Study 1. The energy delivered to the primer simulator will be measured. The above test will be conducted using primer simulators having resistance values of approximately 30,000 ohms, 300,000 ohms and 1,000,000 ohms. The capacitor in each R-C circuit will be charged to the following voltages: 1) 500 volts, 2) 1500 volts, 3) 3000 volts, 4) 4500 volts and 5) 6000 volts. Table 1 lists the tests to be performed using the R-C circuits which represent the average human subject.

Study 3 -- Determination of $\bar{V}$ and threshold voltage required to ignite a cased M52A3B1 primer. The capacitors in the R-C circuits, which represent the average human subject for each environmental condition evaluated, will be used to energize the primer. The $\bar{V}$ voltage will be obtained by performing a 50 primer Bruceton sensitivity test. The threshold voltage is defined as the smallest voltage at which some of the primers are ignited. When determining threshold voltage the applied voltage will be varied in small increments testing 50 primers per increment. It is suggested that the voltage increment be approximately 200 volts. The $\bar{V}$ and threshold voltage will be determined on three lots of M52A3B1 primers assembled in M103 cases. These primers will differ only in resistance level as follows: Lot ES-1, 10000 to 50,000 ohms, Lot ES-2, 100,000 to 500,000 ohms and Lot ES-3, 800,000 to 1,200,000 ohms. Table 2 lists the test conditions for which the $\bar{V}$ and threshold voltage are to be obtained. Also determine the energy delivered to the primer at both the threshold and $\bar{V}$ voltages.

Study 4 -- Determination of the amount of stored charge on a human subject which can be delivered to a primer simulator under simulated field conditions. This study is being conducted to determine if a M52A3B1 primer can be fired by a charged human subject and/or charged implement carried by said subject under simulated field conditions. This study will be performed by having the charged subject stand on an insulated platform and approach the primer simulator, fabricated in study 1, such that the subject's finger, mitten or implement carried by subject is extended so as to touch the simulator. At least one implement chosen by the technical supervisor will be evaluated. When the subject is discharged the energy received by the simulator will be measured. The subject will be charged to the following voltages: 1) $\bar{V}$, 2) $\bar{V} + 3\sigma$, and 3) that voltage where 100 percent of the primers can reasonably be expected to fire if subject is electrically connected to the primer. This study will be performed using primer simulators whose resistance values are approximately 30,000 ohms, 300, 000 ohms and 1,000,000 ohms. Only two of the three human subjects from study 1 are to be used in this study. The subjects shall be chosen such that their capacitances are at the extremes of those measured. Table 3 lists the tests to be performed in this study.

The following safety precaution should be adhered to when conducting the above tests.

When conducting primer sensitivity tests the primed case should be held in a fixture such that the primer output can be prevented from injuring personnel in the area. Caution also must be maintained against backing out of the primer from the case after primer ignition if the base of the primer is not supported.

The government will provide the following materials to the contractor for this procurement: 1) Environmental clothing for human test subjects and 2) Three lots of primers required in study 3.

From the data obtained in the four studies the probability of ignition of the M52A3B1 primer from a human subject is to be estimated when the subject is charged to voltages of 800, 2400 and 4000 volts and 1) subject approaches cased primer and 2) subject is electrically connected to the cased primer.

Progress will be reported in monthly letter reports which will contain all detailed test data and all findings and recommendations will be summarized in a final report.

TABLE 1

STUDIES 1 AND 2. MEASURE THE ENERGY DELIVERED TO THE PRIMER SIMULATOR FOR THESE TEST CONDITIONS WHEN THE ENVIRONMENT IS +40°F AND 30% RELATIVE HUMIDITY.

Resistance of Primer Simulator Kilohms	Charge on Subject or Capacitor Volts
30	500
30	1500
30	3000
30	4500
30	6000
300	500
300	1500
300	3000
300	4500
300	6000
1000	500
1000	1500
1000	3000
1000	4500
1000	6000

Notes: 1. Above tests are to be repeated for following environmental conditions: 0°F. (no humidity requirement) and -40°F. (no humidity requirement).

2. For study 1 the above tests are to be performed on three human subjects.

3. For study 2 the above tests are to be performed using the appropriate R-C circuit for each environment.

TABLE 2

STUDY 3. OBTAIN $\overline{V}$ AND THRESHOLD VOLTAGE FOR THESE TEST CONDITIONS USING THE APPROPRIATE R-C CIRCUIT FOR EACH ENVIRONMENT

Primer Lot	Resistance Level Kilohms	Environment
ES-1	10-50	+40°F (30% relative humidity)
ES-2	100-500	+40°F (30% relative humidity)
ES-3	800-1200	+40°F. (30% relative humidity)

Note: Above tests are to be repeated for the following environment conditions: 0°F (no humidity requirement) and -40°F (no humidity requirement)

TABLE 3

STUDY 4. MEASURE THE ENERGY DELIVERED TO PRIMER SIMULATOR FROM HUMAN SUBJECT AND IMPLEMENT HELD BY SUBJECT FOR THESE TEST CONDITIONS WHEN THE ENVIRONMENT IS +40°F AND 30% RELATIVE HUMIDITY

Resistance of Primer Simulator Kilohms	Charge on Subject Volts
30	$\bar{V}$
30	$\bar{V} + 3\sigma$
30	100% firing voltage
300	$\bar{V}$
300	$\bar{V} + 3\sigma$
300	100% firing voltage
1000	$\bar{V}$
1000	$\bar{V} + 3\sigma$
1000	100% firing voltage

Notes: 1. Above tests are to be repeated for the following environmental conditions: 0°F (no humidity requirement) and -40°F (no humidity requirement)

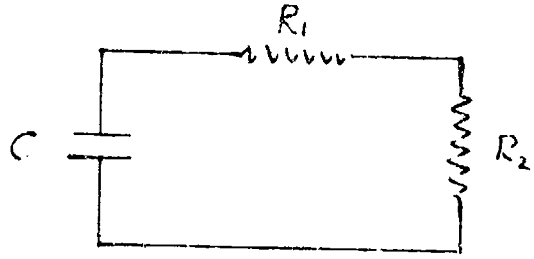
2. Above tests are to be performed on two human subjects

Appendix

B

METHOD B OF COMPUTING SERIES RESISTANCE
OF PERSONNEL DRESSED IN ARCTIC CLOTHING
DURING DISCHARGE

Series Resistance Calculations From Human Circuit Discharges



Assumed Equivalent Circuit

(1) Resistance By Energy Division

Energy on Capacitor $\quad W_T = \frac{1}{2} C V^2$

Energy to R_1 $\quad W_{R_1} = W_T \cdot \frac{R_1}{R_1 + R_2}$

Energy to R_2 $\quad W_{R_2} = W_T \frac{R_2}{R_1 + R_2}$

From These Equations

$$R_1 = R_2 \left(\frac{W_T}{W_{R_2}} - 1 \right)$$

R_1 - Unknown Series Resistance

R_2 - Simulated Resistance (Known)

W_T - Computed

W_{R_2} - Measured From Wave Form

(2) RESISTANCE BY TIME CONSTANT

FOR THE EQUIVALENT CIRCUIT, THE VOLTAGE AS A FUNCTION OF TIME STARTING AT THE INSTANT C BEGINS TO DISCHARGE IS

$$E(t) = E_0 e^{-t/RC}$$

When $t = RC$

$$\frac{E(t)}{E_0} \cong .37$$

The time to achieve 37% of some preselected voltage was measured on the oscilloscope trace. The time lapse from start to the 37% point (t_0) is then used with the measured capacitance (C) to give the total resistance R.

$$R = \frac{t_0}{C}$$

But $R = R_1 + R_2$

AND R_2 is the known simulator resistance

Then $R_1 = R - R_2$ the series resistance

(3) Resistance By Peak Voltage

As C is discharged into R_1, R_2, the voltage will divide proportionally across the two resistors

$$\frac{E_{R_2}}{E_T} = \frac{R_2}{R_1 + R_2}$$

Solving this equation for R_1

$$R_1 = R_2 \left(\frac{E_T}{E_{R_2}} - 1 \right)$$

E_T - Initial Voltage on C
E_{R_2} - Peak Voltage on R_2
R_2 - Resistance of Simulator

SERIES RESISTANCE COMPUTED BY THE THREE METHODS DESCRIBED EARLIER

Simulator Resistance (K ohms)	Subj.	Energy Method: On Body (Ergs)	Energy Method: To Load (Ergs)	Energy Method: Series Resis (K ohms)	Time Constant Method: Time Const (u sec)	Time Constant Method: Total Resis (K Ohms)	Time Constant Method: Series Resis (K ohms)	Temp (oF)
30	S	1980	1540	8.57	1.5	34.09	4.1	40
	M	2520	1730	13.7	1.7	30.357	.357	
	L	2070	2330	----	2.1	45.7	15.7	
300	S	1980	1360	136.8	13	295	----	
	M	2520	2070	65.2	18.5	330	30.4	
	L	2070	1730	59	17.4	378	78,3	
1000	S	1980	1050	886	44	1000	0	
	M	2520	1240	1032	52	929	----	
	L	2070	1190	740	46	1000	0	
30	S	630	251	45.2	.58		11.4	0
	M	675	269	28.8	.64		12.7	
	L	675	177	84.1	.54		6.0	
300	S	630	160	881	5.4		85.7	
	M	675	154	1010	6.4		126.7	
	L	675	142	1122	4.4		----	
1000	S	630	252	1500	17.5		250	
	M	675	131	4128	11		----	
	L	675	168	3016	14.5		----	
30	S	630	261	42.3	.58		11.4	-40
	M	675	344	28.8	.64		12.7	
	L	720	263	52	.56		5.0	
300	S	630	257	435	6.0		129	
	M	675	281	419	6.2		113	
	L	720	172	95.5	4.8		0	
1000	S	630	180	2500	23.5		679	
	M	675	202	2330	14.0		----	
	L	720	183	2920	13.5		----	

Resistance by Peak Voltage Method (K ohms)

		+40	0	-40
30	S	6.59	32.5	27.7
	M	6.59	30.0	13.8
	L	5.71	41.4	32.5
300	S	105	450	325
	M	65.9	518	300
	L	94.7	450	414
1000	S	389	876	1500
	M	415	1239	974
	L	501	1206	1083

Appendix

C

SENSITIVITY TESTING FROM
EQUIVALENT HUMAN CIRCUITS

Functioning Levels (ζ)	2838	3006	3184	3373	3573	3785	4009	4247	4499	FUNCT. TIME secs	RESISTANCE Ω	ITEM NO.
				X								1
			O									2
				X								3
			X									4
		O										5
			O									6
				X								7
			X									8
		O										9
			O									10
				O								11
					O							12
						X						13
					X							14
				O								15
					X							16
				O								17
					X							18
				O								19
					O							20
						O						21
							O					22
								X				23
							O					24
								O				25
									X			26
								X				27
							X					28
						O						29
							O					30
								O				31
									X			32
								O				33
									X			34
								X				35
							X					36
						O						37
							O					38
								X				39
							X					40
						X						41
					O							42
						X						43
					X							44
				O								45
					X							46
				O								47
					O							48
						X						49
					X							50
										n_x =		X
										n_o =		O

i	i^2	n_o	n_x	ζ =
0	0			
1	1			
2	4			
3	9			
4	16			
5	25			
6	36			
Totals:		N_o =	N_x =	

Special Parameters

$c = (\log \zeta)_{i=0}$ = ______

$d = (\log \zeta)_{i+1} - (\log \zeta)_i$ = ______

Primary Statistics

$A = \Sigma\, i\, n$

$B = \Sigma\, i^2 n$

$M = (NB - A^2)/N^2$

$m = c + d\,(A/N \pm 1/2)$*

$\sigma = 1.62\, d\,(M + 0.029)\sqrt{\frac{N}{N-1}}$**

*Use + for "o's;" - for "x's"

**Valid for M ≥ 0.3 only, otherwise consult 'Bruceton Report' (AMP Report No. 101.1R, "Statistical Analysis for A New Procedure in Sensitivity Experiments" July, 1944) File No. Am-1

	For "o's"	For "x's"
A =		
B =		
M =		
m =		
σ =		

Secondary Statistics

$m = \frac{N_o m_o + N_x m_x}{N_o + N_x}$ = ______

$\sigma = \sqrt{\frac{N_o \sigma_o^2 + N_x \sigma_x^2}{N_o + N_x}}$ = ______

ζ = Antilog m = ______

DATE [illegible] INITIALS [illegible] PAGE NO. 23

TEST NO. 3A-1

TYPE OF TEST [illegible]

FREQUENCY

PULSE WIDTH

REP RATE

ITEM ES-1

LOT NO. [illegible]

TEMP. [illegible]

HUMIDITY [illegible]

Functioning Levels (ζ)

Item No.	2838	3006	3164	3373	3573	3725	4009	4247	4449	4765	Funct. Time (secs)	Resistance (Ω)
1					O							
2						O						
3							X					
4						O						
5							X					
6						O						
7							O					
8								X				
9							O					
10								X				
11							X					
12						O						
13							X					
14						X						
15					O							
16						O						
17							X					
18						X						
19					O							
20						O						
21							X					
22						O						
23							X					
24						X						
25					X							
26				X								
27			X									
28		O										
29			O									
30				X								
31			O									
32				O								
33					O							
34						X						
35					O							
36						O						
37							X					
38						O						
39							X					
40						X						
41					X							
42				O								
43					O							
44						O						
45							X					
46						O						
47							X					
48						X						
49					X							
50				O								
X											n_x =	
O											n_o =	

i	i^2	n_o	n_x	ζ =
0	0			
1	1			
2	4			
3	9			
4	16			
5	25			
6	36			
Totals:	N_o =	N_x =		

Special Parameters

$c = (\log \zeta)_{i=o} =$ ______

$d = (\log \zeta)_{i+1} - (\log \zeta)_i =$ [illegible]

Primary Statistics

$A = \Sigma\, i\, n$

$B = \Sigma\, i^2 n$

$M = (NB - A^2)/N^2$

$m = c + d\,(A/N \pm ½)^*$

$\sigma = 1.62\, d\,(M + 0.029)\sqrt{\frac{N}{N-1}}$ **

*Use + for "o's;" - for "x's"

**Valid for M ≥ 0.3 only, otherwise consult 'Bruceton Report' (AMP Report No. 101.1R, "Statistical Analysis for A New Procedure in Sensitivity Experiments" July, 1944) File No. Ma-1

	For "o's"	For "x's"
A =		
B =		
M =		
m =		
σ =		

Secondary Statistics

$$m = \frac{N_o m_o + N_x m_x}{N_o + N_x} = \_\_\_\_\_\_$$

$$\sigma = \sqrt{\frac{N_o \sigma_o^2 + N_x \sigma_x^2}{N_o + N_x}} = \_\_\_\_\_\_$$

ζ = Antilog m = ______

HUMIDITY

TEMP.

LOT NO. ES-1

ITEM

FREQUENCY

PULSE WIDTH

REP RATE

TYPE OF TEST

TEST NO. 3A-1R

DATE [illegible]

INITIALS [illegible]

PAGE NO. [illegible]

Item No.	Functioning Levels (V) 2679	3006	3373	3785	4247	4765	5346	6000	Funct. Time (secs)	Resistance (Ω)
1				X						
2			X							
3		O								
4			O							
5				X						
6			O							
7				X						
8			O							
9				O						
10					O					
11						X				
12					X					
13				X						
14			X							
15		O								
16			O							
17				X						
18			X							
19		O								
20			X							
21		O								
22			X							
23		O								
24			O							
25				X						
26			O							
27				O						
28					X					
29				X						
30			O							
31				O						
32					X					
33				O						
34					X					
35				O						
36					X					
37				O						
38					O					
39						X				
40					O					
41						O				
42							O			
43								X		
44							X			
45						O				
46							X			
47						O				
48							O			
49								X		
50							O			
X									n_x =	
O									n_o =	

i	i^2	n_o	n_x	ζ =
0	0			
1	1			
2	4			
3	9			
4	16			
5	25			
6	36			
Totals:		N_o =	N_x =	

Special Parameters

$c = (\log \zeta)_{i=0}$ = ____________

$d = (\log \zeta)_{i+1} - (\log \zeta)_i$ = [illegible]

Primary Statistics

$A = \Sigma\, i\, n$

$B = \Sigma\, i^2 n$

$M = (NB - A^2)/N^2$

$m = c + d\,(A/N \pm \tfrac{1}{2})$*

$\sigma = 1.62\, d\, (M + 0.029)\sqrt{\frac{N}{N-1}}$**

*Use + for "o's;" - for "x's"

**Valid for $M \geq 0.3$ only, otherwise consult 'Bruceton Report' (AMP Report No. 101.1R, "Statistical Analysis for A New Procedure in Sensitivity Experiments" July, 1944) File No. Ma-1

	For "o's"	For "x's"
A =		
B =		
M =		
m =		
σ =		

Secondary Statistics

$$m = \frac{N_o m_o + N_x m_x}{N_o + N_x} = \_\_\_\_\_\_$$

$$\sigma = \sqrt{\frac{N_o \sigma_o^2 + N_x \sigma_x^2}{N_o + N_x}} = \_\_\_\_\_\_$$

ζ = Antilog m = ____________

DATE [illegible] | INITIALS [illegible] | PAGE NO. [illegible]

HUMIDITY

TEMP.

LOT NO. ES-2

ITEM [illegible]

FREQUENCY ______
PULSE WIDTH ______
REP. RATE ______

TYPE OF TEST [illegible]

TEST NO. 3A-2

Item No.	Functioning Levels (ζ) 4765	5346	6000	6732	7553	8475	9509	Funct. Time (secs)	Resistance (Ω)
1		O							
2			O						
3				O					
4					X				
5				X					
6			O						
7				O					
8					X				
9				X					
10			O						
11				X					
12			O						
13				O					
14					X				
15				O					
16					X				
17				X					
18			X						
19		O							
20			O						
21				O					
22					O				
23						O			
24							X		
25						X			
26					X				
27				X					
28			X						
29		O							
30			O						
31				O					
32					X				
33				O					
34					X				
35				O					
36					X				
37				O					
38					X				
39				X					
40			O						
41				X					
42			O						
43				O					
44					X				
45				X					
46			O						
47				O					
48					O				
49						X			
50					X				
X								n_x =	
O								n_o =	

i	i^2	n_o	n_x	ζ =
0	0			
1	1			
2	4			
3	9			
4	16			
5	25			
6	36			
Totals:		N_o =	N_x =	

Special Parameters

$c = (\log \zeta)_{i=0} =$ ________

$d = (\log \zeta)_{i+1} - (\log \zeta)_i =$ 0.05

Primary Statistics

$A = \Sigma\, i\, n$

$B = \Sigma\, i^2 n$

$M = (NB - A^2)/N^2$

$m = c + d\,(A/N \pm 1/2)^*$

$\sigma = 1.62\, d\,(M + 0.029)\sqrt{\frac{N}{N-1}}$ **

*Use + for "o's;" - for "x's"

**Valid for $M \geq 0.3$ only, otherwise consult 'Bruceton Report' (AMP Report No. 101.1R, "Statistical Analysis for A New Procedure in Sensitivity Experiments" July, 1944) File No. Ma-1

	For "o's"	For "x's"
A =		
B =		
M =		
m =		
σ =		

Secondary Statistics

$$m = \frac{N_o m_o + N_x m_x}{N_o + N_x} = \text{\_\_\_\_\_\_}$$

$$\sigma = \sqrt{\frac{N_o \sigma_o^2 + N_x \sigma_x^2}{N_o + N_x}} = \text{\_\_\_\_\_\_}$$

ζ = Antilog m = ________

HUMIDITY [illegible]

TEMP [illegible]

LOT NO. ES-3

ITEM [illegible]

FREQUENCY ____ PULSE WIDTH ____ REP. RATE ____

TYPE OF TEST [illegible]

TEST NO. 3A-3

DATE [illegible] | INITIALS [illegible] | PAGE NO. 5A

ITEM NO.	4247	4765	5346	6000	6732	7553	8475	9509	10670	FUNCT. TIME (secs)	RESISTANCE (Ω)
1						O					
2							X				
3						O					
4							O				
5								X			
6							X				
7						O					
8							O				
9								O			
10									X		
11								X			
12							O				
13								X			
14							O				
15								X			
16							O				
17								X			
18							X				
19						X					
20					O						
21						X					
22					X						
23				X							
24			O								
25				X							
26			O								
27				X							
28			X								
29		O									
30			O								
31				X							
32			X								
33		X									
34	O										
35		O									
36			X								
37		O									
38			O								
39				O							
40					O						
41						O					
42							X				
43						O					
44							O				
45								X			
46							X				
47						O					
48							X				
49						O					
50							X				
X										n_x =	
O										n_o =	

Functioning Levels (ζ)

i	i^2	n_o	n_x	ζ =
0	0			
1	1			
2	4			
3	9			
4	16			
5	25			
6	36			
Totals:		N_o =	N_x =	

Special Parameters

$c = (\log \zeta)_{i=o}$ = ________

$d = (\log \zeta)_{i+1} - (\log \zeta)_i$ = 0.05

Primary Statistics

$A = \Sigma\, i\, n$

$B = \Sigma\, i^2 n$

$M = (NB - A^2)/N^2$

$m = c + d\,(A/N \pm 1/2)$*

$\sigma = 1.62\, d\,(M + 0.029)\sqrt{\frac{N}{N-1}}$ **

*Use + for "o's;" - for "x's"

**Valid for $M \geqslant 0.3$ only, otherwise consult 'Bruceton Report' (AMP Report No. 101.1R, "Statistical Analysis for A New Procedure in Sensitivity Experiments" July, 1944) File No. Ma-1

	For "o's"	For "x's"
A =		
B =		
M =		
m =		
σ =		

Secondary Statistics

$$m = \frac{N_o\, m_o + N_x\, m_x}{N_o + N_x} = \_\_\_\_\_\_$$

$$\sigma = \sqrt{\frac{N_o\, \sigma_o^2 + N_x\, \sigma_x^2}{N_o + N_x}} = \_\_\_\_\_\_$$

ζ = Antilog m = ________

HUMIDITY

TEMP. 0°F

LOT NO. ES-3

ITEM [illegible]

FREQUENCY ____

PULSE WIDTH ____

REP. RATE ____

TYPE OF TEST [illegible]

TEST NO. 3A4

DATE [illegible] | INITIALS | PAGE NO. 16[illegible]

Functioning Levels (ζ)											FUNCT. TIME	RESISTANCE	ITEM NO.
5346	6000	6732	7553	8475	9509	10670	11970	13430	15070	16910	secs	Ω	
O													1
	O												2
		O											3
			X										4
		X											5
	O												6
		X											7
	X												8
O													9
	O												10
		O											11
			X										12
		O											13
			O										14
				O									15
					O								16
						X							17
					X								18
				O									19
					O								20
						O							21
							X						22
						X							23
					X								24
				O									25
					O								26
						X							27
					X								28
				O									29
					O								30
						O							31
							O						32
								X					33
							O						34
								X					35
							O						36
								X					37
							X						38
						O							39
							X						40
						X							41
					O								42
						O							43
							O						44
								O					45
									O				46
										X			47
									X				48
								X					49
							O						50
											n_x =		X
											n_o =		O

i	i^2	n_o	n_x	ζ =
0	0			
1	1			
2	4			
3	9			
4	16			
5	25			
6	36			
Totals:	N_o =		N_x =	

Special Parameters

$c = (\log \zeta)_{i=0}$ = ______

$d = (\log \zeta)_{i+1} - (\log \zeta)_i$ = ______

Primary Statistics

$A = \Sigma\, i\, n$

$B = \Sigma\, i^2 n$

$M = (NB - A^2)/N^2$

$m = c + d\,(A/N \pm 1/2)$*

$\sigma = 1.62\, d\,(M + 0.029)\sqrt{\frac{N}{N-1}}$**

*Use + for "o's;" - for "x's"

**Valid for $M \geqslant 0.3$ only, otherwise consult 'Bruceton Report' (AMP Report No. 101.1R, "Statistical Analysis for A New Procedure in Sensitivity Experiments" July, 1944) File No. Ma-1

	For "o's"	For "x's"
A =		
B =		
M =		
m =		
σ =		

Secondary Statistics

$m = \frac{N_o m_o + N_x m_x}{N_o + N_x}$ = ______

$\sigma = \sqrt{\frac{N_o \sigma_o^2 + N_x \sigma_x^2}{N_o + N_x}}$ = ______

ζ = Antilog m = ______

HUMIDITY

TEMP. 0°F

LOT NO. ES-2

ITEM M-2A1B3 Primer

FREQUENCY ______

PULSE WIDTH ______

REP. RATE ______

TYPE OF TEST Cap Discs

TEST NO. 345

DATE 29 Apr 75 | INITIALS [illegible] | PAGE NO. 175

Functioning Levels (ζ)

ITEM NO.	5346	6000	6732	7553	8475	9509	10670	11970	13430	15070	16910	FUNCT. TIME secs	RESISTANCE Ω
1									X				
2								O					
3									X				
4								X					
5							X						
6						X							
7					O								
8						X							
9					X								
10				X									
11			X										
12		O											
13			O										
14				X									
15			X										
16		O											
17			O										
18				X									
19			X										
20		X											
21	O												
22													
23													
24													
25													
26													
27													
28													
29													
30													
31													
32													
33													
34													
35													
36													
37													
38													
39													
40													
41													
42													
43													
44													
45													
46													
47													
48													
49													
50													
X												n_x =	
O												n_o =	

i	i^2	n_o	n_x	ζ =
0	0			
1	1			
2	4			
3	9			
4	16			
5	25			
6	36			
Totals:		N_o =	N_x =	

Special Parameters

$c = (\log \zeta)_{i=o} =$ ______

$d = (\log \zeta)_{i+1} - (\log \zeta)_i =$ ______

Primary Statistics

$A = \Sigma\, i n$

$B = \Sigma\, i^2 n$

$M = (NB - A^2)/N^2$

$m = c + d\,(A/N \pm 1/2)$*

$\sigma = 1.62\, d\,(M + 0.029)\sqrt{\frac{N}{N-1}}$**

*Use + for "o's;" - for "x's"

**Valid for $M \geqslant 0.3$ only, otherwise consult 'Bruceton Report' (AMP Report No. 101.1R "Statistical Analysis for A New Procedure in Sensitivity Experiments" July, 1944) File No. Ma-1

	For "o's"	For "x's"
A =		
B =		
M =		
m =		
σ =		

Secondary Statistics

$$m = \frac{N_o m_o + N_x m_x}{N_o + N_x} = \_\_\_\_\_\_$$

$$\sigma = \sqrt{\frac{N_o \sigma_o^2 + N_x \sigma_x^2}{N_o + N_x}} = \_\_\_\_\_\_$$

ζ = Antilog m = ______

HUMIDITY

TEMP. 0°F

LOT NO. ES-2

ITEM M52A1B3 Primer

FREQUENCY ______

PULSE WIDTH ______

REP. RATE ______

TYPE OF TEST Cap Disc 320 v 4

TEST NO. 3A5

DATE 29 Apr 75 INITIALS [illegible] PAGE NO. 18

Functioning Levels (ζ)											FUNCT. TIME	RESISTANCE	ITEM NO.
6732	7553	8475	9507	10670	11977	13420	15070	16910	18967	21290	secs	Ω	
	O												1
		X											2
	O												3
		X											4
	O												5
		O											6
			X										7
		O											8
			X										9
		O											10
			X										11
		X											12
	X												13
O													14
	O												15
		X											16
	O												17
		X											18
	O												19
		O											20
			X										21
		O											22
			x										23
		X											24
	O												25
		X											26
	O												27
		X											28
	O												29
		X											30
	O												31
		O											32
			O										33
				X									34
			O										35
				O									36
					O								37
						O							38
							O						39
								X					40
							X						41
						O							42
							X						43
						O							44
							O						45
								O					46
									X				47
								O					48
									O				49
										O			50
											n_x =		X
											n_o =		O

i	i^2	n_o	n_x	ζ =
0	0			
1	1			
2	4			
3	9			
4	16			
5	25			
6	36			
Totals:	N_o =	N_x =		

Special Parameters

$c = (\log \zeta)_{i=o}$ = ________

$d = (\log \zeta)_{i+1} - (\log \zeta)_i$ = 0.05

Primary Statistics

$A = \Sigma\, i\, n$

$B = \Sigma\, i^2 n$

$M = (NB - A^2)/N^2$

$m = c + d\,(A/N \pm 1/2)$*

$\sigma = 1.62\, d\,(M + 0.029)\sqrt{\frac{N}{N-1}}$ **

*Use + for "o's;" - for "x's"

**Valid for M ≥ 0.3 only, otherwise consult 'Bruceton Report' (AMP Report No. 101.1R, "Statistical Analysis for A New Procedure in Sensitivity Experiments" July, 1944) File No. Ma-1

	For "o's"	For "x's"
A =		
B =		
M =		
m =		
σ =		

Secondary Statistics

$$m = \frac{N_o m_o + N_x m_x}{N_o + N_x} = \_\_\_\_$$

$$\sigma = \sqrt{\frac{N_o \sigma_o^2 + N_x \sigma_x^2}{N_o + N_x}} = \_\_\_\_$$

ζ = Antilog m = ____

HUMIDITY

TEMP. 0°F

LOT NO. ES-1

ITEM M52A1B3

FREQUENCY ____ PULSE WIDTH ____ REP. RATE ____

TYPE OF TEST Cap. Disc Accept

TEST NO. 3A6

DATE 30 Apr 75 | INITIALS CF | PAGE NO. 19

Item No.	4765	5346	6000	6732	7553	8476	9509	10670	11970	13430	Funct. Time (secs)	Resistance (Ω)
1							X					
2						X						
3					O							
4						X						
5					O							
6						O						
7							X					
8						O						
9							O					
10								X				
11							X					
12						X						
13					X							
14				O								
15					X							
16				O								
17					X							
18				O								
19					X							
20				X								
21			O									
22				X								
23			O									
24				O								
25					O							
26						O						
27							X					
28						X						
29					O							
30						X						
31					X							
32				X								
33			X									
34		O										
35			X									
36		O										
37			O									
38				X								
39			O									
40				X								
41			O									
42				X								
43			O									
44				O								
45					O							
46						X						
47					X							
48				X								
49			O									
50				O								
X											n_x =	
O											n_o =	

Functioning Levels (ζ)

i	i^2	n_o	n_x	ζ =
0	0			
1	1			
2	4			
3	9			
4	16			
5	25			
6	36			
Totals:	N_o =		N_x =	

Special Parameters

$c = (\log \zeta)_{i=o}$ = ______

$d = (\log \zeta)_{i+1} - (\log \zeta)_i$ = 0.05

Primary Statistics

$A = \Sigma\, i\, n$

$B = \Sigma\, i^2 n$

$M = (NB - A^2)/N^2$

$m = c + d\,(A/N \pm 1/2)^*$

$\sigma = 1.62\, d\,(M + 0.029)\sqrt{\frac{N}{N-1}}$ **

*Use + for "o's;" - for "x's"

**Valid for M ≥ 0.3 only, otherwise consult 'Bruceton Report' (AMP Report No. 101.1R, "Statistical Analysis for A New Procedure in Sensitivity Experiments" July, 1944) File No. Ma-1

	For "o's"	For "x's"
A =		
B =		
M =		
m =		
σ =		

Secondary Statistics

$$m = \frac{N_o\, m_o + N_x\, m_x}{N_o + N_x} = \_\_\_\_\_\_$$

$$\sigma = \sqrt{\frac{N_o\, \sigma_o^2 + N_x\, \sigma_x^2}{N_o + N_x}} = \_\_\_\_\_\_$$

ζ = Antilog m = ______

DATE 2 May 75 | INITIALS [illegible] | PAGE NO. 20<

TEST NO. 3A7 | TYPE OF TEST [illegible] | FREQUENCY | PULSE WIDTH | REP. RATE | ITEM [illegible] | LOT NO. ES-1 | TEMP. -40°F | HUMIDITY | [illegible]

Functioning Levels (ζ) 7553	8477	9509	10670	11970	13430	15070	16910	18970	21290	23890	FUNCT. TIME secs	RESISTANCE Ω	ITEM NO.
O													1
	O												2
		X											3
	X												4
O													5
	X												6
O													7
	O												8
		X											9
	O												10
		O											11
			X										12
		X											13
	O												14
		O											15
			O										16
				O									17
					O								18
						O							19
							X						20
						O							21
							O						22
								X					23
							X						24
						O							25
							O						26
								O					27
									O				28
										X			29
									X				30
								O					31
									X				32
								O					33
									X				34
								O					35
									X				36
								O					37
									X				38
								X					39
							O						40
								O					41
									X				42
								O					43
									O				44
										X			45
									X				46
								O					47
									X				48
								O					49
									X				50
											n_x =		X
											n_o =		O

i	i^2	n_o	n_x	ζ =
0	0			
1	1			
2	4			
3	9			
4	16			
5	25			
6	36			
Totals:	N_o =		N_x =	

Special Parameters

$c = (\log \zeta)_{i=o}$ = ______

$d = (\log \zeta)_{i+1} - (\log \zeta)_i$ = ______

Primary Statistics

$A = \Sigma\, i\, n$

$B = \Sigma\, i^2 n$

$M = (NB - A^2)/N^2$

$m = c + d\,(A/N \pm \frac{1}{2})^*$

$\sigma = 1.62\, d\, (M + 0.029)\sqrt{\frac{N}{N-1}}$ **

*Use + for "o's;" - for "x's"

**Valid for M ⩾ 0.3 only, otherwise consult 'Bruceton Report' (AMP Report No. 101.1R, "Statistical Analysis for A New Procedure in Sensitivity Experiments" July, 1944) File No. Ma-1

	For "o's"	For "x's"
A =		
B =		
M =		
m =		
σ =		

Secondary Statistics

$$m = \frac{N_o\, m_o + N_x\, m_x}{N_o + N_x} = \_\_\_\_\_\_$$

$$\sigma = \sqrt{\frac{N_o\, \sigma_o^2 + N_x\, \sigma_x^2}{N_o + N_x}} = \_\_\_\_\_\_$$

ζ = Antilog m = ______

HUMIDITY Amb RH 45%

TEMP. -40°F

LOT NO. ES-2

ITEM M52A1E5 Primer

FREQUENCY ______ PULSE WIDTH ______ REP. RATE ______

TYPE OF TEST Cap Disch ≈20µf

TEST NO. 3A8

DATE 5 May 75 | INITIALS [illegible] | PAGE NO. 21<

Item No.	Functioning Levels (ζ): 8475	9509	10670	11970	13430	15070	16910	18970	21290	23890	Funct. Time (secs)	Resistance (Ω)
1			O									
2				X								
3			O									
4				X								
5			O									
6				X								
7			O									
8				X								
9			X									
10		O										
11			X									
12		O										
13			O									
14				O								
15					X							
16				O								
17					O							
18						O						
19							O					
20								X				
21							X					
22						O						
23							O					
24								O				
25									X			
26								X				
27							X					
28						O						
29							O					
30								O				
31									X			
32								X				
33							O					
34								O				
35									O			
36										X		
37									O			
38										X		
39									X			
40								X				
41							O					
42								O				
43									X			
44								O				
45									O			
46										X		
47									X			
48								O				
49									X			
50								O				
X	n_x =											
O	n_o =											

i	i^2	n_o	n_x	ζ =
0	0			
1	1			
2	4			
3	9			
4	16			
5	25			
6	36			
Totals:	N_o =		N_x =	

Special Parameters

$c = (\log \zeta)_{i=o} =$ ______

$d = (\log \zeta)_{i+1} - (\log \zeta)_i = 0.05$

Primary Statistics

$A = \Sigma\, i n$

$B = \Sigma\, i^2 n$

$M = (NB - A^2)/N^2$

$m = c + d\,(A/N \pm \tfrac{1}{2})$*

$\sigma = 1.62\, d\,(M + 0.029)\sqrt{\frac{N}{N-1}}$ **

*Use + for "o's;" - for "x's"

**Valid for $M \geqslant 0.3$ only, otherwise consult 'Bruceton Report' (AMP Report No. 101.1R, "Statistical Analysis for A New Procedure in Sensitivity Experiments" July, 1944) File No. Ma-1

	For "o's"	For "x's"
A =		
B =		
M =		
m =		
σ =		

Secondary Statistics

$m = \frac{N_o\, m_o + N_x\, m_x}{N_o + N_x} =$ ______

$\sigma = \sqrt{\frac{N_o\, \sigma_o^2 + N_x\, \sigma_x^2}{N_o + N_x}} =$ ______

ζ = Antilog m = ______

HUMIDITY: Amb R.H. 55%

TEMP. -40°F

LOT NO. ES-3

ITEM M52A1BC

FREQUENCY ______
PULSE WIDTH ______
REP. RATE ______

TYPE OF TEST: Cap Disc

TEST NO. 349

DATE 10 [illegible]

INITIALS [illegible]

PAGE NO. 22